Ultraviolet radiation (biology)

Article by:

Giese, Arthur C. Department of Biological Sciences, Stanford University, Stanford, California.

Last updated: 2015

DOI: https://doi.org/10.1036/1097-8542.719900 (https://doi.org/10.1036/1097-8542.719900)

Content Hide

Electromagnetic radiation in the wavelength range of 4 to 400 nanometers that affects biological organisms. The ultraviolet portion of the spectrum includes all radiations from 4 to 400 nanometers (nm). Radiations shorter than 200 nm are absorbed by most substances, even by air; therefore, they are technically difficult to use in biological experimentation. Radiations between 200 and 300 nm are selectively absorbed by organic matter, and produce the best-known effects of ultraviolet radiations in organisms. Radiations between 300 and 390 nm are relatively little absorbed and are less active on organisms. Ultraviolet radiations, in contrast to x-rays, do not penetrate far into larger organisms; therefore, the effects they produce are surface effects, such as sunburn and development of D vitamins from precursors present in skin or fur. The effects of ultraviolet radiations on life have, therefore, been assayed chiefly with unicellular organisms such as bacteria, yeast, and protozoa, although suspensions of cells of higher organisms, for example, eggs and blood corpuscles, have been useful as well.

Ultraviolet radiation in sunlight at the surface of the Earth is restricted to the span from about 287 to 390 nm, although shorter wavelengths are present beyond our atmosphere, as shown by measurements with rockets. Consequently, artificial sources of the radiations are generally used in experimentation. *See also:* **Ultraviolet radiation (/content/ultraviolet-radiation/719800)**

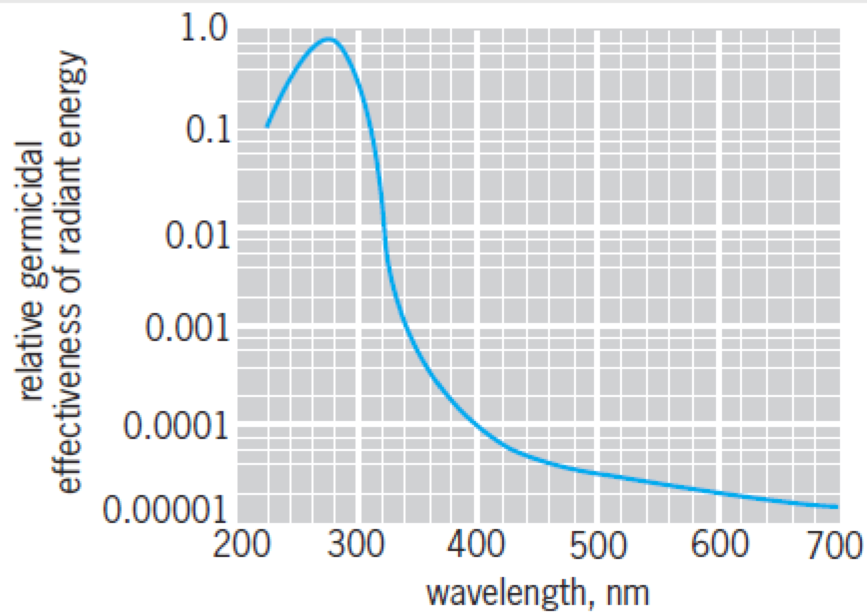
Photobiological effects

Only the ultraviolet radiations that are absorbed can produce photobiological action. All life activities are shown to be affected by ultraviolet radiations, the effect depending upon the dosage. Small dosages activate unfertilized eggs of marine animals, reduce the rate of cell division, decrease the synthesis of nucleic acid, especially in the nucleus, reduce the motility of cilia and of contractile vacuoles, and sensitize cells to heat. Large dosages increase the permeability of cells to various substances, inhibit most synthetic processes, produce mutations, stop division of cells, decrease the rate of respiration, and may even disrupt cells. The effect of ultraviolet radiations upon cells is invariably deleterious.

Despite their damaging effects, ultraviolet radiations are used as tools in biological research because they stop certain cell activities selectively without introduction of extraneous chemicals. They have been found especially useful in the production of mutations in microorganisms. *See also:* **Mutation (/content/mutation/441200)**

Action spectra

Some wavelengths of ultraviolet radiations are more effective than others. More bacteria are killed by a given dosage of ultraviolet radiation at 260 nm than by the same dosage of radiation at 300 nm. When the bactericidal effectiveness of each of a series of wavelengths is plotted against the wavelength, the resulting curve is an action spectrum for the bactericidal effect (see **illustration**). Action spectra have been determined for many other effects of ultraviolet radiations. Each action spectrum is postulated to represent the absorption spectrum of the substance in the cell that is responsible for the particular effect. For the bactericidal effect, production of mutations, and retardation of cell division, the action spectrum suggests absorption by nucleoproteins of nucleic acid. For sensitization to heat and inhibition of ciliary movement, the action spectrum suggests absorption by ordinary proteins. For permeability, another action spectrum exists.



Relative bactericidal action of near-ultraviolet and visible regions for *Escherichia coli* on agar. (*After A. Hollaender, ed., Radiation Biology, vol. 2, McGraw-Hill, 1955*)

Mechanism

The effect of a given dosage of ultraviolet radiation upon protozoan cells is greater when the radiation is flashed than when continuous, that is, if a period of radiation is followed by a period of darkness. This indicates that a thermal reaction follows the primary photochemical reaction, a suggestion which is substantiated by the fact that increasing the temperature within the viable range accentuates the effect of flashing.

Action upon deoxyribonucleic acid (DNA), present in large amounts in chromosomes, consists primarily of the formation of pyrimidine dimers, chiefly between adjacent thymine residues on a strand. They interfere with replication of the DNA.

Photoreversal

The action of ultraviolet radiation on cells can be reversed to a considerable degree by simultaneous or subsequent exposure of the irradiated cells to short wavelength visible, violet and blue, or long wavelength ultraviolet light. This process has been called photoreversal or photoreactivation. Thus, nucleic acid synthesis, inhibited by ultraviolet radiations, is resumed after exposure to visible light. At the same time, cell division, previously inhibited or retarded, is resumed. It appears that those effects of ultraviolet radiation having a nuclear site are most readily photoreversed.

Photoreversal consists of breaking of the thymine dimers into monomers, so reconstituting DNA in its original form. For this purpose, a photoreactivating enzyme, which attaches itself to the dimers, is required as well as light.

Photoreversal is never complete; therefore, photoreactivated cells act as if they had been given a smaller dosage of ultraviolet radiations. It is evident that to make most effective use of ultraviolet radiations as a tool in experimental work, cells must be protected from visible light.

Dark repair

In addition to photoreactivation, it is now known that many cells kept from replication of DNA (in nonnutrient solutions) undergo dark repair. Pieces of DNA-containing dimers are excised (excision enzyme) and replaced on the basis of the information present in the other strand of DNA. Another enzyme (ligase) fastens the piece in place at the open end. Ultraviolet-resistant strains have very effective dark repair systems, whereas UV-sensitive ones do not.

Effects of ultraviolet on the skin

Erythema is the reddening of the skin following exposure to ultraviolet radiation of wavelength shorter than 320 nm, wavelength 296.7 nm being most effective. These radiations injure cells in the outer layer of the skin, or epidermis, liberating substances which diffuse to the inner layer of the skin, or dermis, causing enlargement of the small blood vessels. A minimal erythemal dose just induces reddening of the skin observed 10 h after exposure. A dose several times the minimal gives a sunburn, killing some cells in the epidermis after which serum and white blood cells accumulate, causing a blister. After the dried blister peels, the epidermis is temporarily thickened and pigment develops in the lower layers of the epidermis, both of these factors serving to protect against subsequent exposure to ultraviolet.

Both thickening of the epidermis and tanning may occur without blistering. Since the pigment in light-skinned races develops chiefly below the sensitive cells in the epidermis, it is not as effective as in dark-skinned races where the pigment is scattered throughout the epidermis. Consequently, the minimal erythemal dose is much higher for the dark- than for the light-skinned races.

Pigmentation or tanning also appears when the skin of young individuals is subjected to massive doses of ultraviolet radiations longer than 320 nm. Presumably this occurs by oxidation of precursors of the pigment, melanin, already present in the epidermis. Since such radiation is strong in sunlight, a skin may tan even in absence of short radiations.

Excessive exposure to ultraviolet radiation has been found to lead to cancer in mice, and it is claimed by some to cause cutaneous cancer in humans. *See also:* **Melanoma (/content/melanoma/413750)**

Clinical use

Ultraviolet radiations were once used extensively in the treatment of rickets, many skin diseases, tuberculosis other than pulmonary, especially skin tuberculosis (lupus vulgaris), and of many other diseases. The enthusiasm for sun bathing is, in part, a relic of the former importance of ultraviolet radiation as a clinical tool. Vitamin preparations, synthetic drugs, and antibiotics have either displaced ultraviolet radiations in such therapy or are used in conjunction with the radiations.

Ultraviolet radiations alone are still employed to treat rickets in individuals sensitive to vitamin D preparations. In conjunction with chemicals, they are used in treating skin diseases, for example, psoriasis, pityriasis rosea, and sometimes acne, as well as for the rare cases of sensitivity to visible light. They are also often used to sterilize air in hospitals. In some European laboratories, they are still used as adjuncts to drugs for treating lupus vulgaris and some other forms of tuberculosis. Ultraviolet radiations, however, are probably more important in research than in clinical practice. *See also:* **Radiation biology (/content/radiation-biology/566500)**; **Tuberculosis (/content/tuberculosis/713400)**; **Vitamin D (/content/vitamin-d/734400)**

Arthur C. Giese

Links to Primary Literature

N. D. Paul et al., Ecological responses to UV radiation: Interactions between the biological effects of UV on plants and on associated organisms, *Physiol. Plantarum*, 145(4):565–581, 2012 DOI: https://doi.org/10.1111/j.1399-3054.2011.01553.x (https://doi.org/10.1111/j.1399-3054.2011.01553.x)

Additional Readings

K. N. Prasad, *Radiation Injury Prevention and Mitigation in Humans*, CRC Press, Boca Raton, FL, 2012

American Cancer Society: Ultraviolet (UV) Radiation (http://www.cancer.org/cancer/cancercauses/radiationexposureandcancer/uvradiation/uv-radiation-toc)